them to contract as the speed increased. The governor measured by contraction the velocity of the engine, while the thermometer measured by expansion the velocity in the particles of matter which surrounded it; so that it could now be seen that having to perform two operations, the one on a visible scale, the other on a molecular scale, the same class of mechanism had been unconsciously adopted in performing both operations.

The purpose for which these kinetic engines was put forward was not that they might be expected to simplify the theory of thermodynamics, but that they might show what was being done. The theory of thermodynamics could be deduced by the laws of motion from any one of these kinetic engines, just as Rankine deduced it from the hypotheses of molecular vortices.

Nothing had yet been said of the third part which heat played in performing work, namely, conveying heat in and out of matter. It was an innovation to introduce such considerations into the subject of thermodynamics, but it properly had a place in the theory of heat-engines. It was on this part that the speed at which an engine would perform work depended.

The kinetic machines showed this. If one end of a chain was shaken, the wriggle ran along with a definite speed, so that a definite interval must elapse before sufficient agitation was established to raise the bucket; further, an interval must elapse before the agitation could be withdrawn, so that the bucket might be lowered for another stroke. The kinetic machine, with the pump, could only work at a given rate. He could increase this rate by shaking harder, but then he expended more energy in proportion to the work done. This exactly corresponded with what went on in the steam-engine, only owing to the use of separate vessels, the boiler, cylinder, and condensers, the connection was much confused. But it was clear that for every h.p. (2,000,000 ft.-lbs. per hour) 15,000,000 ft. lbs. had to be passed from the furnace into the boiler, as out of the 15,000,000 no more than 2,000,000 could be used for work; the remaining 13,000,000 were available for forcing the heat into the boiler and out of the steam in the condenser, and they were usefully employed for this purpose.

The boilers were made as small as sufficed to produce steam, and this size was determined by the difference of the internal temperatures of the gases in the furnaces, and the water in the boiler; and whatever diminished this difference would necessarily increase the size of the heating surface required, *i.e.* the weight of the engine. The power which this difference of temperature represented could not be used in the steam-engine, so it was usefully employed in diminishing the size of the engine.

Most of this power, which in the steam-engine was at least eight times the power used, was spent in getting the heat from the gases into the metal plates, for gas acted the part of conveyance far less readily than boiling water or condensing steam. If air had to be heated inside the boiler and cooled in the condenser with the same difference of temperature, there would be required thirty or forty times the heating surface—a conclusion which sufficiently explained why attempts to substitute hot air for steam had failed. In one respect the hot-air engines had an advantage over the steam-engine. During the operation in the cylinder the heat was wanted to be kept in the acting substance; this was easy with air, for it was such a bad conductor of heat, that unless it was in a violent state of internal agitation it would lose heat but slowly, although at a temperature of 1000 degrees and the cylinder cold.

Steam, on the other hand, condensed so readily that the temperature of the cylinder must be kept above that of the steam. It was this fact which limited the temperature at which steam could be used. Thus, while hot air failed on account of time economy, the practical limit of the economy of steam was fixed by the temperature which a cylinder would bear. These facts were mentioned because at the present time there appeared to be the dawn of substituting combustion-engines in place of steam-engines.

Combustion-engines, in the shape of guns, were the oldest form of steam-engine. In these, the time required for heating the expansive agent was zero, while they had the advantage of incondensible gas in the cylinder, so that if the cylinder was kept cool it cooled the gas but slightly, although this was some 3000 degrees in temperature.

The disadvantage of these engines was that the hot gas was not sufficiently cooled by expansion, but a considerable amount of the heat carried away might be used again could it be extracted and put into the fresh charge; to do this, however, would introduce the difficulty of heating-surface in an aggravated form. However, supposing the cannon to have been tamed and coal and oxygen from the air to be used instead of gunpowder. Thermodynamics showed that such engines should still have a wide margin of economy over steam-engines, besides the advantage of working with a cold cylinder and at an unlimited speed. The present achievement of the gas-engine, stated to be some 2,000,000 ft.-lbs. per lb. of coke, looked very promising, and it was thus not unimportant to notice that whatever the art difficulties might be, thermodynamics showed no barrier to further economy in this direction, such as that which appeared not far ahead of what was already accomplished with steam-engines.

But however this might be, he protested against the view which seemed somewhat largely held that the steam-engine was only a semi-barbarous machine, which wasted ten times as much heat as is used—very well for those who knew no science, but only waiting until those better educated had time to turn their attention to practical matters, and then to give place to something better. Thermodynamics showed the perfections not the faults of the steam-engine, in which all the heat was used, and could only enhance the admiration in which the work of those must be held who gave, not only the steam-engine, but the embodiment of the science of heat.

PROFESSOR AUGUST WEISMANN ON THE SEXUAL CELLS OF THE HYDROMEDUSÆ[1]

PROF. WEISMANN of Freiburg is most highly skilled and most indefatigable in research, and all the memoirs which he publishes are of extreme scientific importance, and abound in original views and suggestions which render them of peculiar and widely spread interest. His "Studien zur Descendenz Théorie," his researches on the Daphnoids and on the fauna of Lake Constance, which are known to all naturalists, may be mentioned as examples of his work. Since the spring of 1878 till the present year he has been engaged in investigating the mode of origin of the gonad elements of the Hydromedusæ, and the results are embodied in the present splendid work, which consists of a volume of text of about 300 pages quarto and twenty-four most beautifully executed coloured plates, the whole representing a vast amount of laborious research. Some portions of the results have already appeared in short preliminary papers, but they form a very small instalment of what is here put forth. In the course of the investigation, which has extended to thirty-eight species of Hydromedusæ, important new observations on the habits and composition of Hydroid colonies generally and on their histology were made, and the results of these are fully described here, since most of them have a direct bearing on the elucidation of the main subject of the monograph. The work thus forms secondarily, as stated in the title-page, "a contribution to the knowledge of the structure and vital phenomena of the Hydromedusæ generally."

The principal value of the work, however, lies in the importance of the bearings of the results of the investigations detailed in it upon the general question of the origin of gonad cells. The Hydromedusæ were selected as the subject of research because they appeared to be of all groups of the animal kingdom best adapted for the purpose both because of the transparent nature of their tissues and because they present in closely allied forms so many remarkable differences in the development of the gonad elements.

The work commences with an historical introduction, which can be but briefly referred to here. The question of the origin of the sexual elements in the Hydroida has undergone several important transformations. Prof. Huxley, when he first defined the body of the Medusa as consisting of two layers of tissue—ectoderm and endoderm, raised the question in which of the two layers do the gonad elements originate, and at first concluded that they were formed between the two, and subsequently in 1859, from physiological considerations mainly, that they must originate in the ectoderm. As soon as the advance of histological method permitted accurate direct observation to be made on the matter, Keferstein and Ehlers showed that in the Siphonophora with well developed medusoid sexual individuals, the Calycophoridæ and male Physophoridæ, the germinal cells are developed in what is now recognised as the ectoderm of the manubrium;

[1] "Die Entstehung der Sexualzellen bei den Hydromedusen." Zugleich ein Beitrag zur Kenntniss des Baues und der Lebenserscheinungen dieser Gruppe, von Dr. August Weismann, Professor in Freiburg-i-Br. (Jena: G. Fischer, 1883.)

whilst in the female Physophoridæ the origin of the single ovum is different (in the endocodon). As soon as the homogeny of the two layers of the Cœlenterata with the two primitive layers of the higher Metazoa became evident, the question arose whether the germinal cells of the Metazoa generally were of ectodermal or endodermal origin, and a large number of observers attempted to settle the question offhand by investigating the process of development of the germinal cells in some one Cœlenterate. Each assumed that his particular results must hold good for the entire group, and as the results were conflicting—the place of first appearance of the germinal cells lying as is well known in some Cœlenterates in the ectoderm and in others in the endoderm—much confusion arose. At this period, E. van Beneden's memoir appeared which, on the strength of the conditions occurring in a Hydractinia, a Campanularia, and a Clava, started the theory that the germ layers were themselves sexually differentiated, the female elements arising from the endoderm and the male from the ectoderm, and that in the union of a derivative of each layer lay the essence of impregnation, the necessary precursor of reproduction. This brilliant conception was soon shown by further observation to be erroneous, and as Prof. Weismann points out it was from the first not in accordance with the phenomena of parthenogenesis. As the next important phase in the question came the attempt of the brothers Hertwig to prove that the Cœlenterata belong to two distinct stocks, the one consisting of the Anthozoa and Scyphomedusæ, in which the germinal cells are derived from the endoderm (Endocarpæ), and the other of the Hydromedusæ and Ctenophora, in which they originate from the ectoderm (Ectocarpæ). If this position be correct, and, as will be seen in the sequel, one of the most startling of the conclusions arrived at in the present work is that, notwithstanding all the apparent evidence to the contrary, it probably is so in reality, then the important principle of inheritance and continuity in development in the germ layers receives a strong support, of which with regard to the gonad elements it seemed in great need. Prof. Weismann was led to undertake the present prolonged researches by his observing that in certain of the Hydromedusæ the germinal cells originate, not in the sexual individuals themselves nor even in the blastostyles that support them, but in the cœnosarc of the colony, in the common parenchym of the stem and its branches, and that this occurs not only in the case of the female but also in some instances in that of the male germinal cells. The existence of ovicells of cœnosarcal origin had been previously observed by Quatrefages, F. E. Schultze, Fraipont, and others, but these elements had not been recognised as the sole source of supply of the female gonophores with ova. E. van Beneden further had observed the origin of the egg-cells in Hydractinia, in that part of the blastostyle which subsequently becomes evaginated to form the gonophore. Kleinenberg published his account of his discovery of the migration of the egg-cells of Eudendrium from the ectoderm into the endoderm and in the opposite direction just before Weismann had arrived at a similar conclusion and had found in his preparations egg-cells in the act of boring through the basement membrane with one half lying in the ectoderm and the other in the endoderm. The establishment of the fact that migration of the sexual cells of a most remarkable character in the many forms in which he has proved it to occur is a constant phenomenon, the history of its details, and the discussion of the phylogenetic origin and general biological bearings of the curious phenomena presented by it, form the most important features of the present work.

The author as more convenient adopts—instead of Allman's terms, phanerocodonic gonophore and adelocodonic gonophore—"medusa" and "medusoid gonophore" respectively. He applies the latter term to all gonophores, not becoming free medusæ, in the walls of which any traces, however rudimentary, can be detected of the three layers, viz. the inner and outer ectoderm layers and the intervening endoderm lamella—of which the wall of the bell of the medusa is composed. He uses the term sporophore for those gonophore sacs in which no indication of anything beyond a single layer of ectoderm and endoderm can be discovered.

A structure which assumes great importance in the history of the wanderings of the ovicells is the duplicature of ectoderm, which grows inwards at the summit of the simple sac-like bud out of which a medusa is formed, depressing the endoderm lamella and forming the hollow of the bell. It is necessary that this embryonic organ or mass of cells, observed by so many investigators, should receive a special name, and it is termed "endocodon."

It is pointed out that each hydranth of a colony does not consist alone of that part containing the stomach and bearing the tentacles and hypostome, but also of a stem-shaped portion, which is developed at the same time with it out of the same bud. This region is termed the "hydrocope," and is included in the hydranth, the remaining region of which is the "hydro-

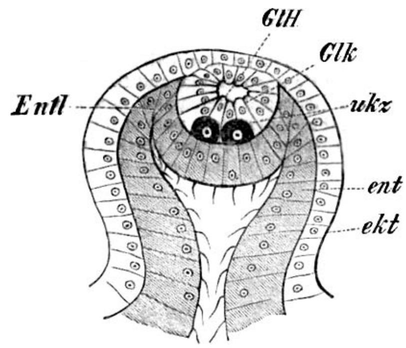

FIG. 1.—Diagram of a bud of a medusa or medusoid gonophore.—*Glk*, endocodon; *GlH*, sub-umbrella space; *Entl*, primitive endoderm lamella; *ukz*, primitive germ cells; *ent*, endoderm; *ekt*, ectoderm.

cephalis." The hydrocope corresponds to the region in Tubularia which Allman terms hydrocaulus, but not to the whole system of stems and branches in an arborescent colony. In such colonies the production of buds is entirely confined to the hydrocope and its counterpart in the blastostyle, the "gonocope."

In the Tubularinæ it is necessary to distinguish amongst the

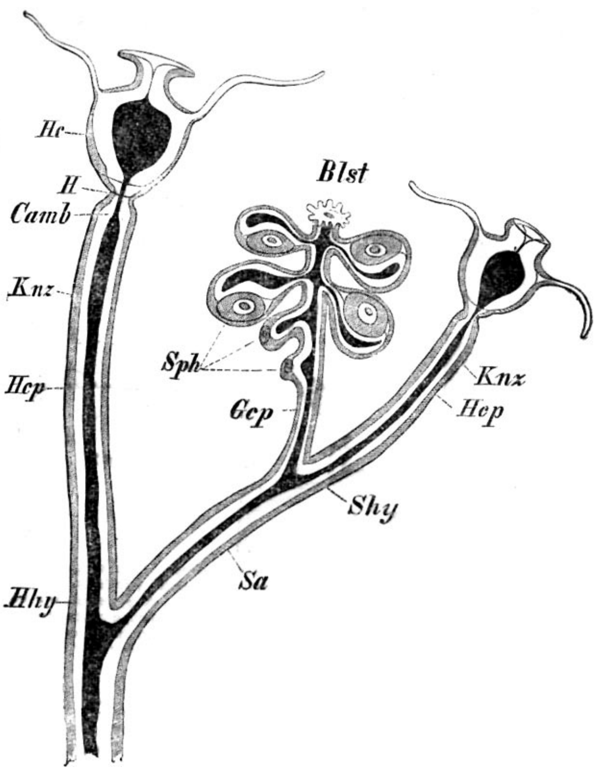

FIG. 2.—Diagram of a primary, *Hhy*, and lateral, *Shy*, hydranth of Eudendrium; *Hc*, hydrocephalis; *H*, neck; *Camb*, cambium zone; *Knz*, zone of gemmation; *Hcp*, hydrocope; *Sa*, lateral branch; *Blst*, blastostyle; *Gcp*, gonocope; *Sph*, sporophore.

hydranths of a stock the "principal" from the "lateral" hydranths. The principal hydranths are those which remain permanently at the extremities of the stems or branches throughout the growth of the stock by lateral budding. In the arborescent stocks of the Tubularidæ the first hydranth sprung from the egg remains permanently at the extremity of the

principal stem, the lateral buds of which never surpass it in growth. In the same way the first formed hydranth of each lateral branch retains its position at the tip of that branch, and must be distinguished as a principal hydranth of secondary order, becoming such so soon as it produces a hydranth bud above its distal gonophore. This distinction is necessary not only because the primary and lateral hydranths often differ in size, but mainly from the most important fact that the principal hydranths are sexually sterile; only the lateral hydranths produce gonophores. No such distinction of principal hydranths occurs amongst the Campanularidæ and the Sertularidæ.

The above brief historical sketch and preliminary explanation is extracted from the introductory part of the work. The special part, which forms by far the greater portion of the whole, treats separately of the details of the series of species investigated.

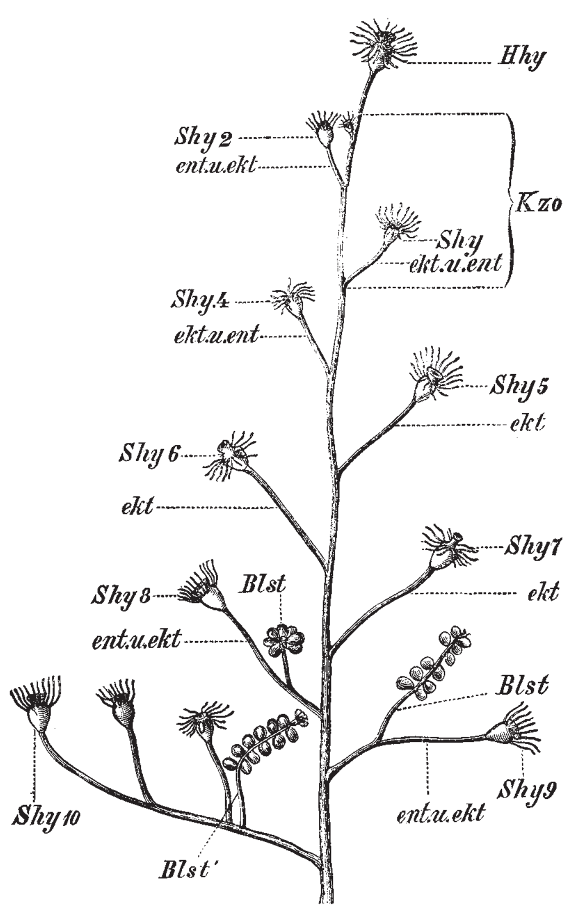

FIG 3.—Tip of a stem of *Eudendrium racemosum* (actual, not d agrammatic), with the principal hydranths, *Hhy*, and ten lateral hydranths, *Shy* 1-10; *Blst*, blastostyle, with female gonophores or ova; *Kzo*, germinal zone in wider sense, *i.e.* extent of the main stem and hydrocope containing egg-cells. The letters *ent* and *ect* indicate whether in the lateral hydrocopes of the specimen ovicells were present in the ectoderm or endoderm, or in both.

The results with regard to two of these forms, *Cordylophora lacustris* and *Eudendrium*, will be followed here, the former being chosen mainly because the account of it is illustrated by a woodcut, which it is advantageous to reproduce. The structure of *Cordylophora lacustris* is well known from F. E. Schulze's most excellent most excellent monograph. Weismann finds that the regular branching of the stock in this species depends on its following the law that "a principal or terminal hydranth of a principal stem or lateral branch produces no buds but those of hydranths, never those of gonophores, and that only the hydranths, and not the gonophores, can produce buds." The zone of gemmation of the hydranths lies in the hydrocope, just below the neck. In the female stocks the germinal cells do not take their origin in the gonophores, but arise in the cœnosarc in the ectoderm of the zone of gemmation of a principal hydranth and in this well defined and restricted region only.

The ovicells are certainly not preformed in the embryo or larva, but are formed in the zone before the lateral hydranth bud begins to appear out of ectoderm cells which differ in no respect from other young ectoderm cells. The ovicells migrate in the ectoderm from their place of origin to that where the bud of the lateral hydranth has begun to form, and, passing into the lateral hydrocope as it grows out, enter the gonophore as soon as it is developed, their entire course of travel lying in the ectoderm. Every ovicell becomes an ovum, and enough ovicells migrate in a group into the lateral hydranth to fill several gonophores; those not destined for the first formed gonophore move onwards past it, and a part of them pass later into the second gonophore when this becomes formed between the first and the neck of the lateral hydranth. This change of position of the ovicells must be partly due to active movement, since the simple shifting due to growth could not push the cells past the first gonophore, and long before the first gonophore is ripe these cells are found lying beyond it, whereas beforehand they lay below it (see Fig. 4, *wz*).

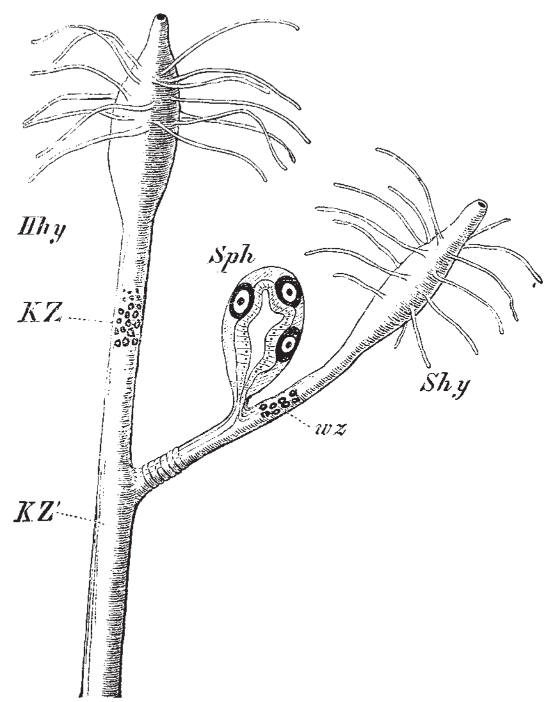

FIG 4.—A principal hydranth, *Hhy*, and a lateral hydranth, *Shy*, of Cordylophora; *KZ*, actual germinal zone, also zone of gemmation; *KZ'*, former position of the germinal zone, *Sph*, female sporophore; *wz*, migrating ovicells.

The migration must take place very slowly and in a particular direction, for the cells are never found scattered irregularly along the whole stem, but always together in a small troop, and they never make their way by accident into a hydrocephalis. The same process is repeated in the formation of the second, and, if ovicells enough be present, of the third gonophore. A fresh swarm of ovicells is never introduced from the main stem into a lateral branch, and no new ovicells are developed in any lateral hydranth until it ceases to become such by developing a hydranth bud above its distal gonophore. It then becomes a principal hydranth of secondary order, and acquires at once a germinal zone beneath its neck, which supplies the gonophores developed on its lateral hydranth buds with ova by migration, just as in the case of the primary principal hydranth. It produces no further gonophores itself, and differs in no respect from the primary principal hydranth excepting in that it was once a lateral hydranth, and produced a set of gonophores, whilst the primary principal hydranth never was lateral and never produced gonophores. The ova ripen in the ectoderm of the sporophores.

The primitive male germinal cells in Cordylophora are formed like the female from young ectoderm cells, but their place of origin

lies in the zone of gemmation of the lateral hydranth at the spot where the gonophore bud is formed.

In the genus Eudendrium most remarkably there is a difference in the formation of the gonad elements in the case of different species. In *Eudendrium racemosum* the gonophores are not borne by the hydranths but on blastostyles, which bud out only from the lateral hydranths. Both male and female germinal cells have their place of origin not in the gonophores or blastostyles, but in the cœnosarc; the gonophores are only the ripening places of the cells. The blastostyles are not regarded by the author as hydranths which in an ontogenetical sense become atrophied in the history of each colony, in consequence of the exhaustive effect of the development of gonophores on them, but as special structures probably derived originally from hydranths, but which have undergone a permanent phylogenetic modification (at all events in *E. racemosum* and *E. capillare*) to adapt them for their peculiar function. The developing buds from which blastostyles are formed are very early to be distinguished from those forming hydranths, and do not vary in colonies of the same sex, though they show a constant difference in form in the two sexes. The male blastostyles have no hypostome, mouth, or trace of tentacles. The female have also no hypostome but have a double crown of tentacles, and appear at the time when the gonophores are ripe to have a small temporary mouth, which it is suggested may possibly swallow the spermatozoa to effect fertilisation.

In the female stocks of *Eudendrium racemosum* when in full sexual maturity the cœnosarcal tubes at all the free ends of the branches contain large quantities of ovicells. The fine twigs are often full of hundreds of them. They occur in both ectoderm and endoderm, but far more abundantly in the former, where they are found in all stages of development, whereas in the endoderm scarcely any but large egg-cells are found. The primitive germinal cells are derived from ordinary young ectoderm cells, with which in rapid process of multiplication the whole germinal zone is filled. This zone lies only in the principal hydranths, commencing a little below their necks and extending a shorter or further distance down the stem, but as a rule not further than the second lateral hydranth (*Kzo*, Fig. 3). Within this zone the production of new ovicells is almost entirely restricted to its uppermost region. As the principal hydranth grows, the germinal zone, which maintains a constant length, rises with it, and as soon as it rises above the point of junction of any lateral hydranth, this hydranth is cut off from any further supply of ovicells. The ovicells never occur in the endoderm within the germinal zone, but are only found in that layer within the hydranth and gonocope. This is because of the remarkable migrations which the cells perform, which take place in perfectly definite directions at definite times. The cells remain in their place of origin, the ectoderm of the germinal zone, until a new lateral hydranth bud begins to be formed, and into this they migrate through the ectoderm, not at once, but as soon as the hydranth has attained a well defined stem. They wait here in the ectoderm, growing considerably, until they have attained a certain size, and then bore their way into the endoderm, nearly all the cells in each lateral hydrocope effecting the penetration of the basement membrane simultaneously, just at the time when a blastostyle bud commences to form. The cells hold on to the basement membrane on its inner face by one end, and stretch forwards the other in the direction of the position of the future blastostyle, and become remarkably elongate, their free ends being drawn out into long slender filaments amongst the endoderm cells. As soon as a hollow is formed in the blastostyle bud they creep in, still clinging to the basement membrane and always to its endodermal face. As the hollow enlarges, more and more creep in, and the bud takes on a pear shape. As the gonophores are budded out from the blastostyle the cells pass into the endoderm of these, then almost simultaneously bore through the basement membrane again, and reach the ectoderm layer of the sporophores, their final ripening place. The ovicells never reach maturity on the hydranths in which they originate, but always in the blastostyle of a lateral hydranth.

In the male stocks of *Eudendrium racemosum* the place of origin of the germinal cells is the ectoderm of the region of gemmation of the lateral hydranths. Thence they migrate by the endoderm into the sporophores, and then like the ovicells bore their way out into their ripening place, the ectoderm of the sporophores.

In the other species of Eudendrium examined, *E. capillare*, the place of first appearance of both male and female germinal cells is in the endoderm.

The results obtained as to the history of the generative elements in the various species examined are given in a concise tabular form under a series of headings, the importance and distinctness of which will now be recognised. The case of Podocoryne is taken as an example. The German terms are not easy to find English equivalents for.

Podocoryne carnea

Keimstätte. Germinal place. (Layer in which the earliest appearance of the germinal cells can be detected.)	Male germinal cells: the ectoderm. Female germinal cells: the endoderm.
Keimzone Germinal zone. (Region of the colony where these cells are earliest detected.)	In male stocks: the manubrium of the Medusa buds. In female stocks: the endoderm sac of the gonophore bud.
Abkunft. Actual origin of the most primitive germinal cells, (in very many cases a matter of inference only).	Male germinal cells: young ectoderm cells. Female germinal cells: probably ectoderm cells which have migrated into the endoderm.
Ripening place.	The ectoderm of the manubrium of free-swimming Medusæ.
Migrations.	The male cells none. The female cells out of the primary endoderm sac of the gonophore bud into the spadix and thence into the ectoderm of the manubrium.

The facts with regard to all the investigated species, when thus placed in a tabular form, appear at first sight so varied and complicated as to defy all reduction to uniform law. The germinal cells appear to be developed sometimes here, sometimes there, without rule of any kind and without definite relation to the germ layers. A most remarkable fact lies in the circumstance that the greatest differences in these matters occur in closely allied genera and even species. But, since this can occur without affecting the general evidences of these relationships, "the variations must depend on such differences as can occur amongst nearly related forms." And in this circumstance really lies in Prof. Weismann's opinion the key to the whole matter. By careful use of the comparative method, he has arrived at the conclusion that the differences in the position of the place of first appearance of the germs depend on a "phylogenetic shifting" of this position, and have ensued *pari passu* with the degeneration of the primitive free medusæ unto sessile brood sacs. The advantage gained by the animal in the shifting which has brought this about, has lain in the earlier ripening of the gonad elements.

In accordance with a widely accepted view, the sessile gonophores of all the attached hydromedusæ except hydra, are probably to be regarded as degenerated medusæ. In the ancestral medusæ the gonad elements of both kinds originated in the ectoderm of the manubrium, and ripened there as they do now in six out of seven Tubularine genera bearing medusæ examined by the author, viz. Dendroclava, Bougainvillia, Perigonimus, Cladonema, Corymorpha, Syncoryne. Both the origination and ripening of the germinal cells occurred during the free life of the medusæ. Certain causes rendered the free medusa stage disadvantageous, and in many instances the gonophores in consequence became sessile, whilst the sexual elements originated and ripened in them at an earlier stage. At first the elements retained the same place of origin as in the free medusæ, a condition which survives in the medusoid gonophores of the existing Cladocoryne. But it became advantageous that the elements should not wait for their formation by cell division and for their gradual maturation until the process of construction of the gonophores by budding had been completed, and thus the formation of the ovicells became shifted, and appeared in an earlier stage. What may be regarded as a first stage in this process is represented in Pennaria and Tubularia, in which the germinal cells of both sexes first appear in the endocodon (see Fig. 1) of the gonophore bud, being carried afterwards, as development proceeds, to the original ripening place, the manubrium. As a further stage

in the process, the primitively ectodermal germinal cells migrated into the endoderm, and here we find them making their first appearance in all the Tubularinæ bearing medusæ or medusoid gonophores, in which they do not originate in the ectoderm of the manubrium or in the endocodon. Most important is the fact that in Podocoryne and Clava, and other forms, the male elements have a different place of first appearance from the female. In Podocoryne the male germinal cells arise in the ancestral place, the ectoderm of the manubrium; the female, however, first appear in the endoderm of the medusa bud. In Clava the male elements originate in the endocodon; in the female they are first detected in the endoderm of the gonophore stem.

Here the phylogenetic shifting of the place of first differentiation of the germinal cells has operated only in one sex or in one more than the other. In all such cases it is the place of first differentiation of the female elements which has undergone further shifting than that of the male, apparently because, under similar circumstances, owing to their more minute subdivision, spermaries become more easily and rapidly ripened than ovaries. In the case of *Eudendrium racemosum*, already described, three further stages of the shifting back of the place of origin of the germinal cells appear to have been undergone by the female stocks beyond those evidenced in Podocoryne.

In some forms, as in Cordylophora already described, the entire long migration takes place entirely in the ectoderm, and it is plain that the shifting of the place of origin of the germinal cells backwards from the gonophores has taken in different forms two different lines of progress, one into the endoderm, the other through the ectoderm only. It is a remarkable fact that in no real medusa is the place of first appearance of the germinal cells shifted further back than at most to the endoderm of the gonophore. The difference of position of the generative elements in the medusæ of the Campanulariræ is regarded by the author as secondary, derived from a primitive disposition, as in the Anthomedusæ, by phyletic shifting from the manubrium to the radial canals, evidence in proof of which is adduced.

A most intensely interesting section is that devoted to the subject of the migration of the germinal cells. These cells seem to be guided in their movements by an extraordinary instinct. Every ovicell on setting out for its travels appears to have before it a definite route to a particular gonophore, and to follow it with certainty; and, further, to be able to distinguish a young hydranth bud from a young blastostyle bud, never entering the one in error for the other. The migrations may be compared to those of certain birds the young of which are believed by some ornithologists to find their way to their distant home without the aid of any old birds who have already made the journey to guide them. The author suggests that it must be the outcome of an excessively fine sense of minute differences of pressure which enables the ovicells of Podocoryne, after they have bored their way into the ectoderm, to arrange themselves in four longitudinal rows in the interradii of the manubrium, instead of forming an even zone round it. No doubt, as he points out, the same laws are at work here which determine the size, shape, number, and sequence of the cells in every organism; but this free mobility of these germinal cells in the Hydroida, with their definite line of march and goal, is a new factor, to which there seems to be no parallel known in other groups, although migrating cells pursuing comparatively indefinite courses are known in most Metazoa. As having a nearer resemblance to these movements are cited those of the mesoblast cells which are set free from the blastophore of the gastrula larva of Echinoderms, and which arrange themselves in regular order on the inner surfaces of its cavity. That there is no absolute difference between these curious tissue-building migrations and ordinary growth follows from the evident fact that they have arisen phylogenetically out of the formation of organs by ordinary process of growth.

The question of the immediate origin of the primitive germinal cells of the Hydroids is discussed in a most able summary chapter of the utmost interest, but which it is impossible to do justice to here. With regard to the relations of the elements to the two layers, the conclusion is that in all the Hydromedusæ, including the Siphonophora, the actual origin of the primitive germinal cells is from ectoderm cells. In all cases in which the first traces of the germinal cells can only be detected in the endoderm, the parent primitive germinal cells have migrated out of the ectoderm. This position is supported by two lines of argument, the one drawn from the comparison of the various stages in the shifting of the place of origin of the germinal cells exhibited in the various species of Hydromedusæ, and especially in the two sexes of the same species, which points clearly to the original and essential source of both sexual elements having lain in the ectoderm, as is still the case in the primitive, hermaphrodite, freshwater Hydra; whilst the other dwells on the circumstance that in all Hydroids in which the first appearance of the germinal cells takes place in the endoderm, a satisfactory proof of the endodermal origin of these cannot be brought forward. Where they originate in the ectoderm their identity with young ectoderm cells is obvious. When found in the endoderm, at the bases of the peculiar flagellate cells composing this layer, they have a similar appearance to the primitive germinal cells found in the ectoderm, but no connection of gradation between them and the endoderm cells can be detected, nor any subdivision of the endoderm cells tending to their production.

Having arrived at the above conclusion, the author is led to believe, as already mentioned, that the division of the Cœlenterata into Endocarpæ and Ectocarpæ introduced by the brothers Hertwig may very probably still hold good, the Hydromedusæ, with the Siphonophora and Ctenophora, being sprung from a separate phylum of the primitive Cœlenterates from that comprising the Anthozoa and Scyphomedusæ.

The work closes with a reference to the question of the alternation of generations in the Hydromedusæ. Now that the cœnosarcal origin of the germinal cells is proved in so many instances, can the gonophores or medusæ, the sexual cells of which are formed in the cœnosarc of the hydranth or stem before they themselves are begun to be developed, be regarded as sexual individuals? It is obvious that it would lead only to confusion if the old way of regarding the matter was upset. The past history of the gonophores must be taken into account, and the fact that the sexual elements, though now developed at a greater or less distance in many species, formerly undoubtedly originated within the gonophores. If an opposite view were adopted, the absurd difficulty would arise that the male gonophores in some species would have to be taken as sexual individuals and the females in the same species as not.

The author's discovery of the gradual phylogenitic shifting of the place of origin of the sexual elements in Hydromedusæ seems, as he points out, to throw most happy light on the vexed controversy between Brooks and Salensky as to the alternation of generations in the Salpæ. The ovarium in the stolon of the solitary Salpa discovered by Brooks doubtless belonged originally to the sexual chain Salpæ and has become shifted in order to hasten its maturation into the stolon of the nurse, which is no more to be regarded as sexual because of its preparing an ovary for the buds than are the principal hydranths of *Eudendrium racemosum* to be regarded as such because they supply the ovicells to the gonophores borne by the blastostyles. As in so many of the Hydromedusæ, the male elements of the sexual individuals have undergone no corresponding shifting. The discrepancies between the results of the two observers probably depend on the circumstance that the process of phylogenetic shifting has attained, as in Hydromedusæ, different stages of development in the various species. The mode of reproduction of the Salpæ is still to be regarded as a case of alternation of generation, even should Salensky's well founded suspicion that the chain Salpæ are themselves able to produce a second ovary after the first has been used up prove invalid.

The remarkable differences in the development of the germinal cells in nearly allied Hydromedusæ seem to be paralleled to some extent by the extraordinary condition in the early embryology of the Salpæ discovered by Salensky,[1] where the differences occurring in the different species are so great and important that, as he writes, "they hardly bear comparison with one another." In all Salpæ the early segmentation of the ovum takes place as usual, but then "gonoblasts,' cells derived from the epithelium of the egg-follicle, not sexually fertilised elements, suppress the blastomeres, which atrophy whilst the entire embryo is formed from the gonoblasts with or without other unfertilised matter. Salensky calls this extraordinary process, which is without parallel in the rest of the animal kingdom, "follicular budding."

Possibly some of the curious differences as to the extent to which the gonoblasts and parts of the ovary and oviduct enter into the formation of the embryo in Salpæ (Gymnogonæ and Thecogonæ) may be hereafter explained on some such principle as that of Prof. Weismann of "phylogenetic shifting."

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[1] Prof. W. Salensky, "Neue Untersuchungen über die embryonale Entwicklung der Salpen," II. Th. Schluss, "Mittheilungen aus der Zool. Station zu Neapl.," Bd. iv. Heft 3.